Future applications for structural glazing

Structural glazing continues to have success in the field of architecture, leading the European Commission to include this particular technique in the Construction Directive, which will be certified under the European Technical Agreement. The Construction Directive has now produced a state-of-the-art document, regarding structural glazing, to meet stringent performance requirements, thus ensuring total quality and control to building owners. New products have been developed to meet these severe requirements, allowing structural glazing to become a key construction technique and opening up new fields of application.

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STRUCTURAL GLAZING

The need of architects and designers to create a perfectly smooth glazed façade, where the architectural fusion of the building skeleton with the facade could be reached, appeared as early as the Twenties. This kind of facade became a reality only after silicone sealant had been developed in the Fifties, and the SG techniques being made technically possible in the Sixties. Structural glazing is the method of bonding glass, ceramic, metal, stone or composite panels to the frame of a building utilizing the strong and long-term adhesive benefits of silicones.

This technique provides architects with unlimited design possibilities and the concept of a totally glazed façade, while ensuring full performances to the building owner. Silicone sealant not only improves the air and weather-tightness of the structure, but also supports the panels, and increases the rigidity of the façade, while providing a flexible rubber anchorage that absorbs differential movements between dissimilar materials from thermal or even seismic loading.[1]

In structural glazing, the silicone adhesive plays a triple role. It resists the constraints imposed by the effects of wind on the glass elements, combined with a permanent load in the case of unsupported systems, roof glazing or sloped glazing. In addition, it withstands the imposed movement created by the differential thermal dilatation between the glazing element and the internal structure. It is therefore essential to use a sealant material and not a rigid adhesive, as the material should resist both a load and a movement without creating stresses at the glass interface or failing cohesively. Owing to the silicone's excellent adhesion to glass, its thermal stability, its elasticity, and its resistance to UV radiation and ozone, this material proved to be extraordinarily suitable for the composition of such a sealant. The explanation lies in the fundamental chemical properties of this type of material, which are, in fact, close to the glass structure.

NEW EUROPEAN STANDARDS

In 1989, to support free trade and harmonized quality standards for construction products within the European Community, the Construction Products Directive 89/106/EEC was voted. ETA, the European Technical Agreement, is one of the two main types of technical specifications in the sense of the Construction Products Directive that exists to verify that a product satisfies the essential requirements. Interestingly, structural glazing was one of the first façade techniques for which a mandate was voted to produce ETA guidelines. This is maybe due to the particular aura this façade technique has in the mind of people, or due to the number of different standards existing in various countries. But, whatever the reason, it constituted a unique chance to check if such a technique satisfies the modern requirements of a building as defined by a group of international experts.

This work is nearing completion and is already compiled in the ETA guidelines document ETAG 002/July 1998[2]. At the same time, a complete range of new highly performing silicone elastomers, meeting the technical requirements of these stringent standards, have imposed themselves on the market due to their overall product performance. For the architects and building owners this is of great help, as it now represents the state of the art that can be asked from a structural glazing system according to European quality requirements, therefore allowing them to concentrate on the design aspects of their projects.

These guidelines are to be reviewed, as they were published with real life examples of cases, where products have been successfully used according to the essential requirements.

ESSENTIAL REQUIREMENTS

Mechanical resistance and stability

It is important to mention that this guideline covers the four types of four-sided structural glazing systems existing today. These systems differ from one another by the presence of the retaining device and/or mechanical self-weight supports. National regulations should determine which one of these systems is allowed in a country. The economically reasonable working life that is being considered under the construction directives, and not only for structural glazing, is 25 years. This economical lifetime, not to be confused with the technical lifetime of a system, is defined by the period in which, for a given income, the standard maintenance cost for a building remains below the cost of investment for a new construction. When we know that producers generally consider a minimum safety factor of two for the technical lifetime, we directly realize the seriousness of what these guidelines should bring on the performance and durability of, for instance, the silicone sealant used for that particular application.

As an example for special mechanical resistance, the understanding of the capability of the

TABLE 1

FIRE/FUME CHARACTERISTICS FOR DOW CORNING 993 STRUCTURAL GLAZING SEALANT

Oxygen index	35.9%	NF T 51-071
Flammability test	no flammability before 850°C	NF C 20-455
Toxicity of fumes	658 mg/g CO_2 26 mg/g CO	
No HCl, no HCN	NF X 70-100	
Density of fumes	311	
Fumes obscuration level	11	NF X 10-702
Fumes/fire index	12/FO	

silicone adhesives used as structural façade elements has recently opened new developments in the area of safety glazing, such as bomb-blast resistant facades. Tests are carried out on these façades by submitting the elements to a charge of 12 Kg. of TNT placed 0.8 metres above ground level, and at 6.6 metres from the façade. Results confirm how successfully a properly dimensioned structural silicone system can resist both the amplitude and the particular high frequency of the load, rendering silicone structural glazing a very attractive technique for bomb-blast resistant façades. All bomb-blast tests are developed according to prEN standards.

In addition, the resistant and high bonding characteristics provided by silicone also opened new possibilities to increase the resistance of standard façades towards bomb blast, storm or hurricane by gluing with silicone in the frame. The role of silicone bonding in such applications is to increase the resistance of the façade and to avoid any fall of big glass elements.

Safety in case of fire

Requirements of a structural glazing system for the reaction and resistance to fire should be in accordance with laws and regulations. When special glazing is used, for which resistance to fire is claimed, a test can be undertaken according to the relevant European standards. As a minimum, the fire resistance should be as long as the time necessary to the building occupants to safely leave the place in the case of fire. In reality, the resistance to fire is predominantly determined by the performance of the glazing, and not by the silicone adhesive. Indeed, the silicone bond is certainly not the weakest point in the system. Information gathered from real life, where fire occurred near a four-sided structural glazing system, confirmed that the silicone behaved extremely well in the event of fire. Glass breakage and aluminium melting occurred well before the final combustion of the silicone, thus rendering the resistance to fire of such a façade well above those of non-glued systems. In addition, tests made on silicone elastomers have confirmed their extremely low level of smoke density and toxicity, as shown in Table 1. Consequently, when the proper glazing and frame elements are used, structural glazing systems can also be developed as fire resistant.

Hygiene, health and environment

Constructions are to be designed and built in such a way that there may be no threat to the hygiene or health of their occupants or neighbours. Silicone, glass and metal (aluminium or steel) that are traditionally used in SG façades are particularly well suited to respect this requirement.

Other growing issues for modern buildings are aesthetics, maintenance and cost of maintenance. It is well known that any discontinuities in a façade are the source for dirt accumulation and dirt streaking. In addition, while it is generally known that the glass elements of a façade must

TABLE 2

TESTS NEEDED FOR STRUCTURAL SILICONE USED IN STRUCTURAL GLAZING ACCORDING TO ETAG 002

1. PRODUCT IDENTIFICATION	
Specific mass, hardness	Elastic recovery
Thermogravimetric analysis	Shrinkage, gas inclusion
2. INITIAL MECHANICAL STRENGTH	
Tension at rupture and stiffness	Tested at -20, +23 and +80°C Ru, 5
Shear at rupture	Tested at -20, +23 and +80°C Ru, 5
Creep under long-term shear and tensile load	91 days under permanent load
3. ARTIFICIAL AGEING	
Immersion in water at high temperature under UV	1000 h at 45°C in water / statistical analysis
Mechanical fatigue under tension and shear	5000 cycles
Humidity and NaCl	Effect of marine environment / statistical analysis
Humidity and SO_2	Effect of pollution / statistical analysis
4. COMPATIBILITY	
Compatibility with accessories	3 weeks under high temperature and UV radiation
Compatibility with façade cleaning products	3 weeks immersion in products at 45°C

TABLE 3

DISTRIBUTION OF DAMAGE FOR LIGHT FAÇADES ACCORDING TO THEIR CATEGORY(3)

DAMAGE IN LIGHT FAÇADES

% DISTRIBUTION	% OF THE TOTAL NUMBER	% OF THE TOTAL COST OF REPAIR	AVERAGE COST FOR REPAIR (EURO)
STRUCTURAL GLAZING	4.5	5.5	7,851
GLASS FAÇADE	26.4	35.0	8,583
PLASTIC	3.3	3.4	6,738
METAL	33.9	33.8	6,479
WOOD	24.5	15.1	3,994
OTHER LIGHT FAÇADE	7.3	7.2	6,403
TOTAL	100	100	6,494

be cleaned regularly, it is less known, however, that aluminium exposed to the outside must also be cleaned with water and tensides, and rinsed several times per year in order to ensure its durability. The structural glazing technique offers three fundamental advantages on this aspect. Firstly, perfectly smooth glazed façade gives no chance for dirt to get trapped. Secondly, there is an absence of exterior aluminium profile, and, last but not least, this absence of external profile also allows the use of highly automated, easy to use, low labour intensive façade cleaning systems. Studies conducted in Germany confirmed that the extra cost initially encountered due to the erection of a structural glazing façade could be totally compensated during the lifetime of the building by savings mades in terms of maintenance and cleaning costs.

Safety in use

The chapter regarding the subject of safety is the most detailed and important of the guidelines. It summarizes the test procedure imposed on the combination of the structural sealant with the bonding surfaces to assess their mechanical properties and resistance to ageing and degrading agents. A summary of the tests is displayed in Table 2.

A complete series of tests assesses the mechanical performance of a system at various temperatures. A statistical approach is also adopted to know better, from a sampling population, what can be the limit of performance of a system in real-life applications. This statistical approach is also used to ensure that the ageing elements do not induce significant deterioration in the system that would limit its lifetime. Last but not least, compatibility between the different components of a system, but also with the façade-cleaning product, is also assessed in a statistical way. Next to the tests on the structural sealant, it also describes the test methods for the mechanical self-weight supports, the retaining devices, prototype windows, and so on.

It is remarkable but somewhat logical that a study made in France [3] regarding the relative number and damage costs for different types of façade techniques ranked silicone structural glazing well below the traditional glass façade, confirming the reliability of this technique (see Table 3).

Protection against noise

While the acoustics of a façade are primary, being governed by the design (size of the glazed elements, presence of opening lights, type and width of glazing, etc.) and the installation, structural glazing undoubtedly brings additional noise protection compared with standard cladding. This is made possible by achieving the least possible connection of the glass to the building frame, thus avoiding the transmission of disturbing oscillations. In addition, the presence of a silicone "membrane" acts as a damping element. Furthermore, the development of new insulating glass edge systems that can be filled possibly with sound-damping gas (SF6) is also a factor that makes structural glazing a suitable choice when noise reduction is important.[4]

Energy economy and heat retention

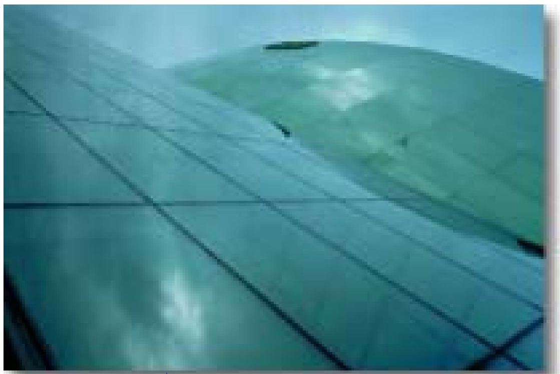
The commitment given at the Kyoto conference by the European Union, in Japan, regarding carbon dioxide emissions, has literally catalyzed new developments in the area of glass and façades in architecture. From passive, façade systems are becoming reactive; they have not only the saving of energy as an objective, but also the supply of energy to the building.

The structural glazing technique is a key element of active façades, as it allows performance while keeping design possibilities, as is proved by the double-skin structurally glazed active façade with the narrow air space of the Grande Bibliothèque National de France.

In the area of windows and insulating glass, the modern

Four-sided structural glazing design at the Grande Bibliothèque National de France, in Paris, France

Bolted glazing system for the Shed Halle in St. Polten, Austria, seen from the inside



External view of the bolted glazing system for the Shed Halle in St. Polten

silicone sealants used as edge seals of insulating glass are now fulfilling the requirements of the latest technologies used to increase performance of double glazing systems such as low-E glass, gas-filled insulating glass and warm-edge technologies. With the commercialization of the silicone (3362) sealed TPS IG system, the structural glazing market can now also take advantage of a warm-edge UV-resistant insulating glass system[5] (see Table 4).

CONCLUSIONS

The review of structural glazing versus the essential requirements has resulted in a document that can now be considered as state-of-the-art, ensuring total quality and control to building owners. This work, together with the new products that have been developed to meet stringent performance requirements, is strengthening structural glazing and making it into a key construction technique for the future, as well as opening up new fields of application. Products that meet the strict requirements of these guidelines should be considered by construction partners as the most reliable materials, thus allowing them to concentrate on the design aspects of their work and the best utilization of the various advantages of structural glazing. One example of this use is the Phoenix project in Brussels, Belgium, where four-sided structural glazing was used with newly-developed high-thermal performing bent glass.

In addition, structural glazing will continue to open new ways to architects and façade designers of demonstrating the creative potential of glass used in façades, and roof and internal applications, using structural, fin, bolted or bonded glazing techniques. An example is the project for the roof of the Shed Halle in St. Polten, Austria, where the glass roof was made based on point-loaded supported glass structure, using a chemical connection based on structural silicone.

It is therefore fundamental that the high quality requirements put forward by these standards not be jeopardized by a too heavy administrative interpretation and weight of these guidelines. Countries where such an approach has already been adopted have found ways to keep the practical use of these guidelines flexible. For instance, the interchange of components or suppliers for components of a SG kit, qualification of glass coating in families, and the interpretation of test reports qualifying sealant structural capability on different surfaces, need to be ensured without heavy administrative procedures involving cost and time.

TABLE 4

GAS LOSS RATE VALUE OF TPS/3362 IG SYSTEM AS TESTED FOLLOWING DIN 1286 PART 2

Samples	Gas loss rate L_E 10^{-3} x a^{-1}	Initial gas concentration	Gas loss in vol. %
1	9.3	97	+7.0
2	9.9	97	+7.0

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This article was first presented at the Sixth Glass Processing Days Conference held in Tampere, Finland